

Asteroid Astrometry from CCD Images

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Abstract

astrometry for asteroid name..etc

1. Introduction

2. Data Reduction

2.1. Systematic Corrections

The purpose of bias, dark, flat correction is to make the intensity of the image approximately linearly proportional to the number of astronomical photons arriving at the detector.

Bias subtraction. Bias frames are images taken with zero integration time and used to subtract the digital offset at zero level. Common practice include taking a scalar value representative of the bias frame dataset (i.e. mean or median) and subtracting that from the original image. For the simple averaging method, the more bias frames we have the better, since as the number of bias frames we have increase, the standard deviation of the mean falls off as $1/\sqrt{N}$, thereby decreasing the uncertainty on the obtained mean value. We applied the method of indiscriminate rejection described by Chromey (2010) which removes the largest pixel value of the bias frame, then take the median on the remaining values. This method rejects the largest statistical outlier which is included when we simply take the mean for correction. Another method of bias correction is to set extra clock cycles so that the

CCD reading continues for an additional 32 pixels after the physical image has been read out. Such use of overscan pixels can be advantageous over bias frames for bias correction in the case when the bias is changing over time since each image has its own bias correction taken immediately after the exposure. We corrected an image by taking the median of the 32 pixel. The median is chosen over the mean so that anomalies such as cosmic ray events or nearby radio activity are rejected. Even though we experimented with all the methods described above, since the goal of this lab is to conduct astrometric measurements using these images rather than detailed photometric study, we have simply chosen the more computationally trivial method of bias frame subtraction to apply to every image.

Dark and Flat Correction. Dark frames are long-exposure images taken with the shutters closed to calibrate for dark responses. We conduct dark correction by subtracting from a single dark frame with exposure time of 300 seconds. Since the CCD for Nickel Telescope is cooled by the LN2 dewar to a relatively low temperature, the thermal production of electrons is much lower than in room temperature. Therefore dark frames will not signifi-

cantly improve the data quality. We took the dark and flat frames for the I,R filters taken on October 16, 2013 and applied them to the other data on the other days since dark and flat frames were not taken for the observation at the other dates. Using the twilight sky as a source of uniform illumination, the flat field images calibrate the pixel-by-pixel variation of each pixel. The exposure time was short and adjusted for every frame to accommodate for the sky's changing brightness. Every pixel on the 1024-by-1024 image is processed by :

$$\frac{\text{image} - \text{dark}}{\text{flat}} \times \text{median}(\text{flat}) \quad (1)$$

As shown in the equation, we first dark-subtract from the image so that the intensity is linearly proportional to the number of photon counts then we divide by the flat in order to scale for the pixel-by-pixel variations. By plotting the pixel histogram of the image, we see that most of the pixel values are very small relative to our original image data at around 0.005 (@@@@UNITSSS). In order to preserve the comprehensible data ranges of the original intensity values after subtraction, the image is normalized by a scalar value that is representative of the magnitude of the flat field data. The median value is chosen because unlike the mean its value is not skewed due to the bad pixel and columns present on the Nickel Telescope.

2.2. Centroid-finding

In order to determine the positions of the stars on the image, we need to find the centroid position with the weight as the First, we set a threshold which was empirically adjusted to yield just enough stars for pattern recognition at around 5000 (UNITSS!!!!). This identifies Since bad columns, corners, and borders often show up as completely dark pixels ¹, it is mistaken as a whole row of stars ,

¹Since image color scheme is inverted, the darkest pixel mean highest intensity.

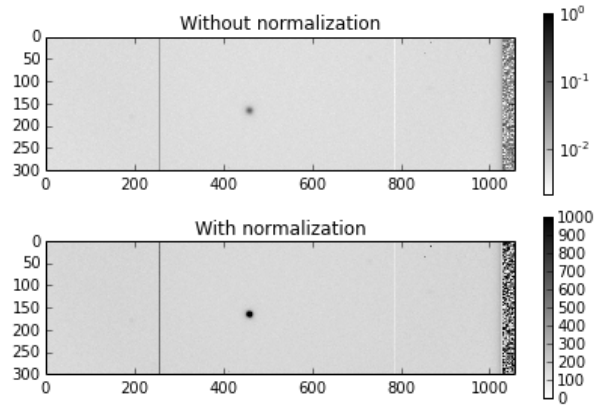


Figure 1: Without normalization, the image requires a logarithmic stretch to distinguish the asteroid and the background since it has to accommodate for the range of decimal values resulted from the division. With normalization, the image can be viewed on a linear scale with a lower intensity limit of 0 and upper limit of 1000.

we have to manually mask the pixels by zeroing the intensity value at the selected pixel. Since this is a fairly trivial case where the dat-

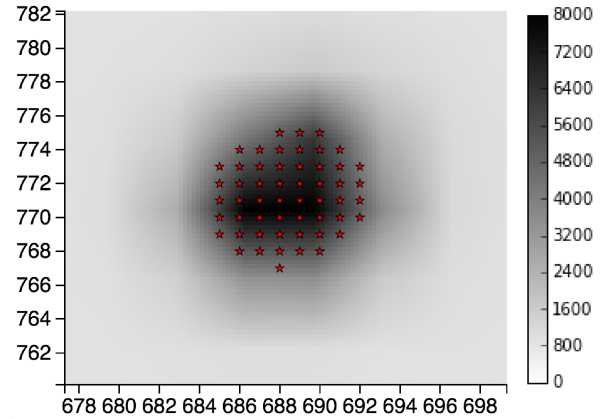


Figure 2: CENTROID MANY STUFF

apoints for each cluster is far apart, we use the more conceptually simplistic but computational intensive method of distance estimation instead of other clustering algorithm in the literature. We loop through list of points above the threshold and for every _ we compute its pixel distance from another point in the same list. If the separation distance between two datapoints is smaller than 20 pixel,

then it is clustered into the same star. Each cluster represent a star. This threshold radius is selected r , most star have approx same aperture/ size because r . Finally, in order to get a representative value from cluster information, we calculate the centroid by Eq. 2 :

$$x = \frac{\sum_i x_i I_i}{\sum_i I_i} \quad (2)$$

Error on centroid.

2.3. Pixel to Standard Coordinate conversion

Since most stars used for (?) comparison are often very far away, it is convenient to treat them as projected position onto a sphere centered at the observer.

3. Astrometry

Using stellar positions to calibrate the image

3.0.1. Algorithm

3.1. Least Square

The purpose of using the least square method is to find a conversion matrix between the CCD-based pixel coordinate to standard coordinate. The standard coordinates can then be projected to celestial coordinates based on the Eq. (LABEL!!!): (TYPE EQUATION HERE)

3.1.1. USNO

intentionally adjust the Vmag lower cut than Vmag observed in NASA's small object dynamic so that it is able to identify the asteroid as a star.

3.2. Ephemeris information

Position vector can be obtained from the HORIZONS Web-Interface heliocentric vector to Earth This could be verified with the vector from earth to asteroid. JPL horizon by default returns the ecliptic coordinate, Make sure to chose equatorial coordinate . This would

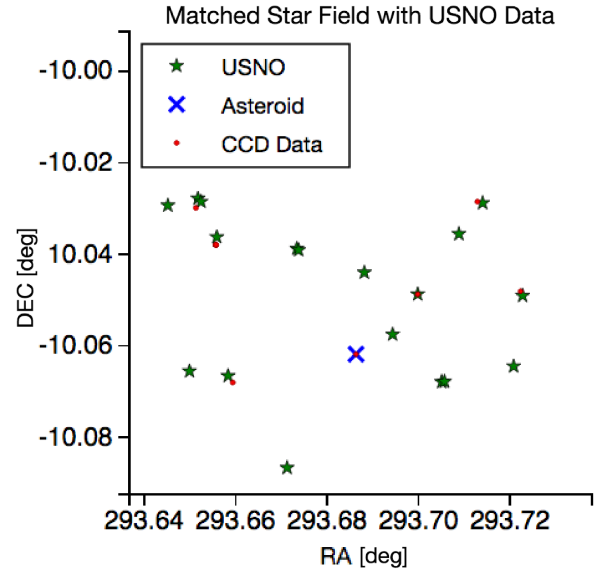


Figure 3: Matching starfield with USNO-B1 of stars with Vmag_i (—), October 16, 2013. The asteroid is easily identified as it shows up on the CCD image but not on the USNO-B1 catalog.

affect the values for y and z components of the position (and velocity) vector returned since in the equatorial system the plane is around the equator

xy-plane: plane of the Earth's mean equator at the reference epoch x-axis : out along ascending node of instantaneous plane of the Earth's orbit and the Earth's mean equator at the reference epoch z-axis : along the Earth mean north pole at the reference epoch

3.3. Iterative solution

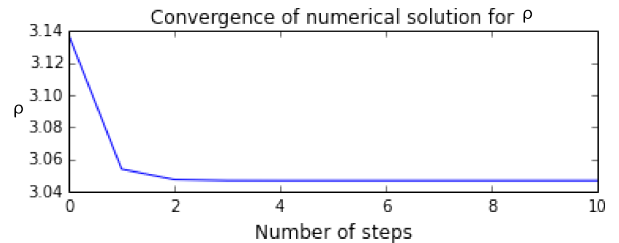


Figure 4: Convergence

From a Monte Carlo simulation of 1000 trials, the solution takes on average 5 steps

to converge² Each step approximately bring closer to the actual solution by an order of magnitude.

4. Error and Uncertainty

4.1. Centroid Error

To find the however this obtained results is in units of pixels,

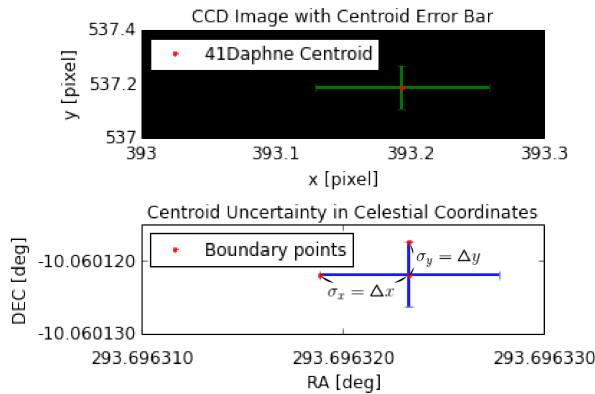


Figure 5: using the same procedure described in Sec (REF!!!) this is converted into units of degree.

4.2. Monte Carlo

4.3. Other possible errors

For this exercise, we only examined errors on the asteroid. However, uncertainty in the measurement of stellar position can also affect our asteroid position result since stellar positions are taken into consideration in the least square procedure. This propagates to uncertainty on the plate constant values we obtain which is used in the calculation for conversion from — to — coordinates. However this effect should be secondary to the ones we computed directly for the asteroid.

5. Conclusion

6. References

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²We define a solution to be converging when the difference between solutions at consecutive steps is less than 1.0×10^{-5}

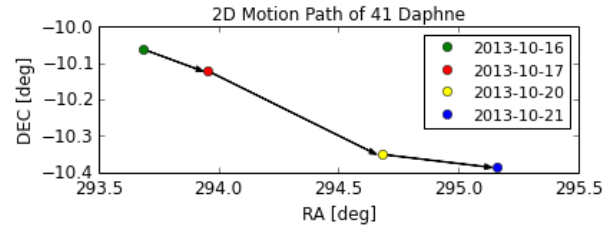


Figure 6: motion path

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